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Complexity in the Evaluation of Contract Types Employed for the Construction of Highway Projects

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Abstract

The procurement of public works is by definition complex in that its success depends on many varied interrelated parties (client, designer, licensing authorities, contractors, construction supervisor, users). In addition, the construction process is always technologically complex as it is comprised of numerous tasks and objectives. The choice of the most appropriate contract type (CT) regarding the method of contractor compensation is one of the most essential and complex decisions. This choice is based on the decision maker's knowledge, experience and intuition. Following an extensive literature review to determine both the seven CT's employed in the construction industry and the nine selection criteria (SC) most commonly considered when choosing between CT's, a questionnaire survey was carried out among 79 highway construction professionals who were asked to rate each CT against each selection criterion. This study presents the frequencies of the CTs scores against each criterion but the main aim of the research is to decompose the complex selection patterns relating to the participants' choices. A correlation analysis carried out established associations among the respondents' profiles and their resulting ratings of each CT against each SC. The results indicate that the participants' origin, current position profile, years and type of professional experience and finally years of direct and indirect experience with each CT influence their perception of the appropriateness of each CT against each criterion and the respective scores awarded to each CT.

Keywords: Contract type; highway projects; project stakeholders; statistical analysis; correlations; complexity

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1. Introduction

Vidal *et al.* (2011) argue that the definition of project complexity could be summarized in the following: "project complexity is the property of a project which makes it difficult to understand, foresee and keep under control its overall behavior, even when given reasonably complete information about the project system". According to Baccarini (1996), "Project complexity can be defined as 'consisting of many varied interrelated parts' and can be operationalized in terms of differentiation and interdependency. This definition can be applied to any project dimension relevant to the project management process, such as organization, technology, environment, information, decision making and systems". The application of complexity theory is to enable the systematic review of the inter-connections. Although the complexity of projects and their environment obviously influences important decisions, complexity as such is often taken intuitively or from previous experiences. In addition, complexity issues include but are not limited to the following:

- Project complexity influences the selection of project inputs
- Complexity is frequently used as a criterion in the selection of a project procurement system
- Complexity affects the achievement of project objectives of time, cost and quality.

The procurement of public works is by definition complex as, from project inception to project realization, it must go through a number of phases and its success depends on many varied interrelated parties. The major participants in the above procedure are the Owner or Client, the Design Consultant, Contractor and Construction Manager (CM). The number and type of contractual relationships between the major participants are crucial in terms of time, cost and quality achievement of the resulting project.

The construction process is considered a complex undertaking as it is comprised of numerous tasks and objectives, the most important of which is obtaining value for money, especially during times of recession. For this reason, the choice of the most appropriate CT regarding the method of contractor compensation is essential. In making this choice, decision makers use their own knowledge, experience and intuition according to specific selection criteria (SC) they have in mind.

This research focuses on the procurement authority participants' thought process and approach to the selection of the appropriate CT for highway construction projects. Each participant is considered a system which processes data and exports a justified opinion, in this case a proposal for a certain CT. The output of the system is the decision on the CT, which is based upon the assessment of certain SC. Each participant influences the others and shapes the final common decision on the best CT to be employed. Their personal assessment of the available CTs against the predefined SC is based on a number of factors, interconnections which are not apparent.

This paper considers all the above issues and focuses on the selection process of the appropriate CT against a predefined number of SC for the construction of public highway projects. The final aim of the current research initiative is to explore the way the profile of the engineer (experience: years, role, duties, type of projects) influence the decisions on the appropriate CT against a number of predefined SC.

2. Methodology

2.1. Determination of contract types and selection criteria

Since the late 1980's early 1990's the importance of choosing the most appropriate CT has been evident in the construction industry (Veld & Peeters 1989; Ward & Chapman, 1994). The literature review showed that for public works CTs and in particular regarding the method of compensation, there are numerous reports relating to: a) the evaluation of their performance in terms of the final cost, duration and/or quality of resulting project (Turner & Simister, 2001; Paul & Gutierrez 2005; Tang *et al.*, 2008;

Meng & Gallagher 2012), b) proposals for new CTs (Boukendour & Bah, 2001; Gruneberg *et al.*, 2007), c) proposals for new or combinations of award criteria (Lambropoulos 2007; Padhi & Mohapatra, 2009) or even modifications of the lowest bid criteria (Wang *et al.*, 2006), d) provision of guidelines for the use of various CT's for particular project types (Jaraiedi *et al.*, 1995; ITA Working Group, 1997; Bower *et al.*, 2002), e) proposals of methods for calculating incentives (Ward & Chapman, 1995; Berends, 2000; Broome & Perry 2002; Shr & Chen, 2003, 2004) and identifying and mitigating the associated risks (Olsen & Osmundsen, 2005; Chan *et al.*, 2011b) and f) motivations for good contracting behavior (Rose & Manley, 2011; Chan *et al.*, 2011a).

In Greece, researchers have been involved in the evaluation of project procurement systems and contractor selection criteria and procedures (Antoniou & Kalfakakou, 2009; Antoniou *et al.*, 2012; Lambropoulos, 2007). To date there is no proposal for implementation, in the Greek public works scene, of a CT defining any other method of payment apart from, the Lump sum/fixed price (LSFP), the Unit price method (UPM) or the Cost Plus Percentage Fee (CPPF). It is therefore essential to consider new CTs for implementation in Greece concerning the procurement of major highway projects. Following this review the seven CTs as defined in Table 1 were selected to be investigated.

Table 1. Contract Type Definitions

Cost plus fixed fee (CPFF) The contractor is reimbursed for all audited costs & paid a fixed amount for the his services.
Cost plus percentage fee (CPPF) The contractor is reimbursed for all audited costs & paid an additional percentage fee.
Cost plus incentive fee (CPIF) All justified costs are paid. Final fee depends on actual compared to target cost, delivery and/or performance achievements.
Incentive/ Disincentive for time reduction (ID/T) The contractor is paid in addition to the agreed payment method a bonus (incentive fee) if the project is completed earlier and pays a penalty (disincentive fee) if it is completed after.
Fixed price incentive (FPI) The contractor is paid actual costs and an agreed upon fee but guarantees a maximum total cost.
Lump sum / fixed price (LSFP) The client pays a fixed price to the contractor irrespective of the actual cost.
Unit price method (UPM) The contractor commits to fixed prices for pre-specified units of work items. Payment is the sum-product of the unit prices and the units used.

The choice of SC was based on the results of an extensive literature review and justification of their choice for inclusion in this research work was presented in Antoniou *et al.*, (2012).

2.2. Questionnaire

This paper attempts to draw conclusions from a survey between highway procurement experts of the rating of each examined CT against a series of selection criteria. The questionnaire survey was conducted during the two last years, 2010 - 2012. The first part of the structured questionnaire that was developed was devoted to the participants, who responded to a number of personal questions regarding their professional background. The aim of the second part was to rate the degree of achievement of each CT against the 9 SC. The SC that were included in the survey were rated on a scale of 1 to 10 as explained in Table 2.

Table 3 depicts the personal profiles of the respondents. The survey was addressed to engineers from Greece and abroad. The survey collected 79 answers from engineers, from contractors, public authorities, funding managing authorities and academians. The questionnaires were completed through interviews and email. From the total of 79 participants 14 are engineers currently involved in highway design, 24 in Construction Supervision and finally 24 respondents are currently employed in project management or what is known in Greece as the Superior Authority. Participants with public sector experience represent

the 77% of the sample while participants with some private sector experience represent 70 % of the pool of respondents. Finally, 66 male and 13 female participants took part in the survey. In addition, the results of the Cronbach's Alpha computation (= 0,916) reveals that the measure has high internal consistency.

Table 2. Explanation of Rating Scale for each Selection Criteria used in Survey

Criteria	Each CT was rated as 10 (on a scale of 1 to 10) if
SC1 Cost Uncertainty	It is appropriate when it is difficult to estimate the final construction cost and the client wishes to avoid the risk of cost escalation
SC2 Uncertainty of Scope	It is appropriate when the technical characteristics of the project are not specifically defined
SC3 Process Uncertainty	It is useful in situations where construction methodologies are unknown at start or are expected to be complex.
SC4 Value for Money	It provides the most efficient method for obtaining value for money
SC5 Criticality of Schedule	It is appropriate when the duration of the contract is critical
SC6 Performance Criticality	It provides incentive for excellent quality and avoids cutting corners.
SC7 Availability of extra resources	It requires adequate staff in numbers and experience to supervise and/or manage the contract.
SC8 Contractual Difficulties	It is simple to implement and does not require specialized calculations
SC9 Claims	It reduces the number of claims expected.

Table 3. Personal profiles of survey respondents

Category	**Respondents**		**Category**	**Respondents**		**Category**	**Respondents**	
	Number	**%**		**Number**	**%**		**Number**	**%**
Current Occcupational Field			**Years of Private Sector Experience**			**Years of Project Management Experience**		
Constuction Supervision (CS)	24	30%	None	24	30%	None	17	22%
Project Management (PM)	25	32%	Below 9 years	25	32%	Below 9 years	21	27%
Design – Research - Funding	10	13%	10-19 years	15	19%	10-19 years	24	30%
Construction - Freelance	18	23%	over 20 years	15	19%	over 20 years	17	22%
Years of Design Experience			**Direct Experience per CT**			**Origin**		
None	36	46%	CPFF	25	32%	Greece	56	71%
Below 9 years	24	30%	CPPF	27	34%	Abroad	23	29%
10-19 years	11	14%	CPIF	11	14%	**Years of Public Sector Experience**		
over 20 years	8	10%	ID/T	19	24%	None	18	23%
Years of Construction Supervision Experience			FPI	7	9%	Below 9 years	17	22%
None	20	25%	LS/FP	52	66%	10-19 years	23	29%
Below 9 years	26	33%	UPM	63	80%	over 20 years	21	27%
10-19 years	24	30%						
over 20 years	9	11%						

Descriptive statistics of the responses were estimated using SPSS v.18 and correlation analysis took place to define the relationships among participants' profiles and their responses. Specifically, the Pearson's chi-square test is used to determine if a relationship between two variables exists by comparing the frequencies observed in certain categories to the frequencies you might expect to get in those

categories by chance. If the significance value is small enough (conventionally less than .05) then the hypothesis that the variables are independent is rejected and confidence in the hypothesis that they are in some way related is gained (Field, 2009). Given that the chi-square statistic is the sum of standardized residuals, in order to decompose what contributes to the overall association that the chi-square statistic measures, the individual standardized residuals are examined as they have a direct relationship with the test statistic. These standardized residuals behave like any other in the sense that each one is a z-score which means that if the value lies outside of ±1.96 then it is significant at $p < .05$. Chi-square test was used to examine the association of participants profile and their assessment of CTs against each SC.

3. Discussion of Results

3.1. Analysis of Resulting Descriptive Statistics

The frequency percentages of the ratings between 1-3, 4-7 and 8-10 were added, giving the total frequency of the low, medium, and high categories respectively. The detailed results of each CT against each SC are presented in the following Tables 4 and 5. A matrix table was developed between CTs and the SC ratings in Table 6 where it can easily be seen whether a CT was given an overall high, medium or low frequency rating against any given selection criterion.

Table 4. Frequency of Ratings of CT's against SC1-SC5 (%)

Criterion	Cost Uncertainty			Uncertainty of Scope			Process Uncertainty			Value for Money			Criticality of Schedule		
Rating	8-10	4-7	1-3	8-10	4-7	1-3	8-10	4-7	1-3	8-10	4-7	1-3	8-10	4-7	1-3
CPFF	22,3	51,8	26	37,7	47	15,1	28,8	52	19,2	28,8	52	19,2	9,5	66,1	24,5
CPPF	18,6	48,2	33,4	40,7	44,5	14,8	32,1	49	18,8	32,1	49	18,8	5,6	66,6	27,8
CPIF	12,8	59,5	27,6	25	64,6	10,4	29,8	68,1	2,1	29,8	68,1	2,1	34,8	59,2	6,1
ID/T	43,8	50,1	6,3	19,1	53,2	27,7	19,5	69,5	10,9	19,5	69,5	10,9	66	30	4
FPI	58,7	37	4,4	21,7	45,7	32,6	21,7	52,2	26,1	21,7	52,2	26,1	17	70,2	12,8
LSFP	58,5	37	4,6	26,5	34,3	39,1	37,1	37,2	25,8	37,1	37,2	25,8	20,3	61	18,8
UPM	24,2	53,1	22,8	33,4	34,8	31,8	21,5	44,6	33,8	21,5	44,6	33,8	9	61,2	29,8

Table 5. Frequency of Ratings of CT's against SC6-SC9 (%)

Criterion	Performance Criticality			Availability of Extra Resources			Contractual Difficulties			Claims		
Rating	8-10	4-7	1-3	8-10	4-7	1-3	8-10	4-7	1-3	8-10	4-7	1-3
CPFF	29,7	46,4	24,2	34,6	57,8	7,6	48,2	48,2	3,7	45,2	45,3	9,4
CPPF	37,1	44,5	18,6	39,6	52,8	7,6	36,3	58,2	5,4	37,1	51,9	11,1
CPIF	60,4	35,4	4,2	41,8	48	10,5	10,4	56,3	33,4	25,1	50	25
ID/T	28,6	57,1	14,2	39,6	52,1	8,4	8,4	75	16,7	25,1	56,3	18,8
FPI	21,3	53,2	25,5	25,5	61,7	12,8	10,6	80,9	8,5	17	74,4	8,5
LSFP	14,1	59,5	26,6	25,1	62,5	12,6	51,6	42,2	6,3	48,5	34,4	17,2
UPM	27,3	59,1	13,6	41,2	45,6	13,2	51,6	42,2	6,3	23,9	61,2	15

Table 6. Most frequent ratings of each CT against each SC

	CPFF	CPPF	CPIF	ID/T	FPI	LSFP	UPM
SC1: Cost uncertainty	Med.	Med.	Med.	Med.	High	High	Med.
SC2: Uncertainty of scope	Med.	Med.	Med.	Med.	Med.	Low	Med.
SC3: Process uncertainty	Med.	Med.	Med.	Med.	Med.	High/ med.	Med.
SC4: Value for money	Med.	Med.	Med.	Med.	Med.	High	Med.
SC5: Criticality of schedule	Med.	Med.	Med.	High	Med.	Med.	Med.
SC6: Performance criticality	Med.	Med.	High	Med.	Med.	Med.	Med.
SC7: Availability of extra resources-	Med.	Med.	Med.	Med.	Med.	Med.	Med.
SC8: Contractual Difficulties	High/med.	Med.	Med.	Med.	Med.	High	Med.
SC9: Claims	High/med.	Med.	Med.	Med.	Med.	High	Med.

The most significant results of this analysis are highlighted as follows:

- The CTs FPI and LSFP were considered by the respondents to fully meet the cost uncertainty SC, i.e. they are appropriate when it is difficult to estimate the final construction cost. These results agree with the Client's expected benefit of these CT's of avoiding the risk of cost escalation as proposed in the literature (Veld & Peeters, 1989; Berends, 2000).
- The CT LSFP is considered not to be appropriate when there is uncertainty of scope, hence fully corroborating with the opinions of researchers (Ward & Chapman 1994; ITA working group, 1996; Turner & Simister, 2001; Boukendour & Bah, 2001).
- Turner and Sinister 2001 evaluated LSFP as useful when there is high uncertainty of the award and contract management process. The respondents agreed with this statement as 34% gave a medium rating and 34% gave a high rating of LSFP against the process uncertainty SC.
- The results of the survey validate the findings of researchers that the LSFP CT is an efficient method for obtaining value for money (Ward and Chapman 1994) and that the ID/T CT is expected to achieve reduction in construction time (Jaraied *et al.*, 1995; Tang *et al.*, 2008).
- The results show that the CPIF CT provides incentive for excellent quality hence again agreeing with Howard *et al.* (1997) that this CT influences the contractor's internal process for better performance.
- The simplest to implement CTs and those that are expected to produce the least amount of contractors claims as rated by the survey respondents are CPFF and LSFP. This is explained by Ward and Chapman 1994 since adverse effects due to potential contractor's loss are avoided.
- No CT was rated as highly requiring adequate staff in numbers and experience to supervise the contract in contrast to the literature that provides that the CPIF is a complicated CT to manage (Bower *et al.*, 2002) as any changes occurring requires renegotiation of the agreed incentive.

3.2. Correlations between participants' profiles and responses

The findings of the correlation analyses are grouped according to the various profiles of the survey participants and presented in the following Tables 7-11. The first column presents the SC and the others show the rating each group tends to provide for each CT. The analysis revealed a number of interesting correlations as follows:

Cost Plus Fixed Fee - Respondents from abroad consider that this CT is useful when construction methodologies are unknown or are expected to be complex and provides incentive for excellent quality.

Cost Plus Percentage Fee - a)Foreign respondents consider this CT to be good where construction methodologies are complex but not when the client wishes to avoid cost escalation and b) respondents

from Greece tend to rate this CT as average regarding the Cost Uncertainty SC.

Cost Plus Incentive Fee - Respondents from abroad consider that this CT is quite simple to implement and is successful in reducing claims, while it requires average number of client staff for supervision purposes on the other hand Greeks tend to disagree on both counts.

Incentive/Disincentive for Time Reduction - a)Foreigners consider that this CT is slightly above average in meeting the uncertainty of scope, criticality of schedule, performance criticality, availability of extra resources and claims SC, b) Greeks agree that this CT is appropriate when there is scope uncertainty and is perfect when there is criticality of schedule and c) construction supervisors tend to rate this CT as appropriate when there is cost uncertainty while project managers and designers disagree.

Fixed Price Incentive - a) Respondents from abroad consider that this CT does not provide quality incentive and b) project managers, designers and contractors believe that this CT increases claims.

Lump Sum Fixed Price - a) Foreigners tend to rate this CT as average, while Greeks consider it ideal in obtaining value for money and b) respondents from abroad believe it is sufficiently simple to implement.

Unit Price Method - a) This CT produced the greatest number of correlations between the profile categorizations of origin and current position which is expected as 80% of the respondents denoted that they have direct experience with this CT. Specifically, it was found that Greek experts consider this CT ideal in obtaining value for money while those from abroad consider it above average and b) while a significant number of correlations between current position and ratings of this CT against the SC were obtained there seems to be no consensus between the 4 categories of current position on any of the SC.

Table 7. Significant tendencies of CT ratings according to origin and current position profiles

	CPFF		CPPF		CPIF		ID/T						FPI						LSFP				UPM					
	Greece	Abroad	Greece	Abroad	Greece	Abroad	Greece	Abroad	CS	PM	Design	Constr.	Greece	Abroad	CS	PM	Design	Constr.	Greece	Abroad	Greece	Abroad	CS	PM	Design	Constr.
SC1			5	1					8	2	3												6		1	7
SC2							8	7																		
SC3		9		9																						
SC4																			10	6	10	7		4	1	3
SC5							10	7																	10	2
SC6		9						7						2										6		3
SC7					10	7		7														3		4	10	3
SC8					1	8														8			8		9	6
SC9						8		7							5	3	7									

Table 8 depicts rating tendencies of the subgroups representing years of design, supervision and project management. The most significant findings are:

Design experience correlations: a) Respondents with less than 10 years design experience tend to rate the CPIF CT as highly successful in achieving the performance criticality SC, while those with more than 10 years provide a rating of less than 2, b) those with greater than 10 years design experience seem to agree that the ID/T is not useful for projects where construction methodologies are unknown at start or are expected to be complex and c) designers with less than 10 years experience are confident that the UPM is appropriate when there is scope uncertainty, while those with greater than 20 years design experience disagree, but on the other hand believe this CT to be useful when the duration of the contract is critical.

Construction Supervision correlations a) Respondents with little supervision experience tend to rate CPPF as below average in achieving the performance criticality SC while those with more experience

provide a much higher rating of 8, b) respondents with little supervision experience tend to rate ID/T as average in terms of the uncertainty of scope and performance criticality SC while those with greater experience have the same opinion with regards to the performance criticality SC and c) as the years of supervision experience increases the ratings of the FPI CT against the uncertainty of scope and process SC diminishes from average to below average.

PM experience (Superior Authority) - As the years of PM experience increases so do the ratings of the FPI CT with regards to the uncertainty of scope SC from slightly below average to above average.

Table 8. Significant tendencies of CT ratings according to years of design, supervision and PM experience

	CPPF				CPIF				ID/T				FPI								UPM			
	CS Exp				Des. Exp.				Des. Exp				CS Exp.				CS Exp.				PM Exp.				Des. Exp.			
	0	0-9	10-19	>20	0	0-9	10-19	>20	0	0-9	10-19	>20	0	0-9	10-19	>20	0	0-9	10-19	>20	0	0-9	10-19	>20	0	0-9	10-19	>20
SC2													3	4		10	7	4		1		4	6	8		10		3
SC3											1	2					6	4	5	1								
SC5																											9	6
SC6	1	4	8			9	1	2						6	5	10												
SC7													7			10												
SC9																	7		3									

In a similar correlation analysis carried out between years of experience in the public and private sector and the resulting ratings (Table 9), the most significant results are from those with more than 20 years experience in the public sector who consider the CT CPIF highly inappropriate when it is difficult to estimate the final construction cost and the client wishes to avoid the risk of cost escalation. Finally, the most experienced in the public services considered the UPM as simple to implement.

Table 9. Significant tendencies of CT ratings according to years of Public or Private Sector experience

	CPPF						**CPIF**					**ID/T**	**FPI**				**LSFP**								**UPM**			
	Priv. Sec				Pub Sec		Priv. Sec			Pub. Sec		Priv. Sec	Pub. Sec				Priv. Sec				Pub. Sec				Pub. Sec			
	0	0-9	10-19	>20	0	10-19	0-9	10-19	>20	0-9	>20	>20	0	0-9	10-19	>20	0	0-9	10-19	>20	0	0-9	10-19	>20	0	0-9	10-19	>20
SC1										8	1																	
SC2	5	3	4	8	9	5																						
SC3		9	5	9									2	9	5	10												
SC4																	7	1	4	9								
SC5																				9					2	10	4	
SC6																					1	8	5	10	3	6	8	
SC8							3	5	8					8		6									6			10
SC9												7	7	3	5													

Strikingly enough very few correlations were found between those with direct experience in a specific CT and their ratings of that CT as shown in Table 10.

Table 10. Significant tendencies of CT ratings by those with direct experience in each CT

	CPFF	CPIF	ID/T	FPI
SC1			7	
SC3	9			
SC 5	1			8
SC8	9	8		

On the other hand, a significant number of correlations were found between those with experience in different CT than the one being rated as shown in Table 11. It would have been expected that those with direct experience in specific CTs would rate them similarly. This in itself proves how complex the choice of CT is, as there is no clear cut choice of CT in case of each SC even by those with direct experience in the management of such contracts.

Table 11. Significant tendencies of CT ratings by those with direct experience in other CT's

Exp. in/ SC	CPFF				CPPF		CPIF			ID/T			FPI				LSFP			UPM		
	CPIF	ID/T	FPI	LSFP	CPIF	ID/T	CPFF	ID/T	LSFP	CPFF	CPPF	CPIF	CPFF	CPPF	CPIF	ID/T	CPFF	CPIF	FPI	CPFF	CPIF	ID/T
SC1												7					7			10		
SC2	9															8			3	8		8
SC3					9		7			7			8							8		8
SC4	1	1		6			3				5				8							
SC5	1					1		7				7	9		9		7	9		2	9	1
SC6												7	2	5	2	2	1			3	3	3
SC7			3									7								9	3	3
SC8			6					8	6				7				7			6		
SC9						10	7			7		7	7				9					

4. Conclusions and Further Research

This study, based on an extensive literature review, first identified the dominant CT against defined SC and argued that the profile of the participant affects his/her own perception of the appropriate CTs. The research indeed produced a ranked list of CTs. The most unique contribution of the current research is the presentation of correlations among survey participants' profiles and their responses concerning the prioritization of the CTs against selection criteria. Indeed the idea of the ideal CT is shaped in the mind of each decision maker according to his / her own perceptions.

The next step of the research will focus on factor analysis and regression analysis. The effort will be partly focused on grouping the CTs. Furthermore, based on the notion that the conception of the CTs is correlated to the profile of the participant, prediction models will be produced to forcast the desired CT, based on the decision makers' profile. Apart from creating different research groups by dividing the sample of participants, one other essential fact which will be taken into consideration is the clustering of data. Clustering or grouping data is the first step towards creating a database. Decisions on data groups affect greatly the analysis results because the denser the groups of data the greater the number of correlations.

Understanding of the perceptions of each participating team member could facilitate the decisions on the selection of the most appropriate contract type. Early recognition of one's ideas could help the

negotiations for the common decisions on the best contract type hence reducing the complexity of decision maker's intuition.

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